

LECTURE 9

Data Analysis III: X-Ray Spectroscopy

XSPEC

- X-ray spectroscopy
- Fit models to spectra
- Interactive
- Command-line driven
- General purpose tool
- Works with most space-based observatories
- Well-supported
- *De facto* standard

Spectral Fitting

- Spectrographs do not record the intrinsic spectrum
- A photon of energy E can be recorded as having an energy E' drawn from a range of energies $E-dE$ to $E+dE$
- The probability of each value of E' can be determined through calibration
- Spectrograph no 100% efficient
- Efficiency depends on energy
- Can be determined through calibration

$$C(I) = \int f(E)R(I, E)dE$$

$C(I)$ = recorded counts in channel I

$F(E)$ = true flux at energy E (intrinsic spectrum)

$R(I, E)$ = response function

Determine $f(E)$ by comparing a model spectrum to the data.

Find the “best fit” in a statistical sense

For example: minimize the chi-squared of the fit

Need some physical understanding of the source to know what model to try and fit.

Using XSPEC

Starting

```
shogun 19> xspec
```

```
    XSPEC version: 12.5.1  
Build Date/Time: Fri Aug 28 16:22:02 2009
```

```
XSPEC12>
```

Set Up

Where to send the plots

```
XSPEC12> cpw /xw
```

What to plot on the X axis

```
XSPEC12> setplot energy
```

Read Data

```
XSPEC12> data PKS0745-19_PC.pi
***Warning: Detected response matrix energy bin value = 0 (or neg).
XSPEC will instead use small finite value (response file will not be
altered).

1 spectrum in use

Spectral Data File: PKS0745-19_PC.pi Spectrum 1
Net count rate (cts/s) for Spectrum:1 1.343e+00 +/- 5.186e-03 (98.4 %
total)
Assigned to Data Group 1 and Plot Group 1
Noticed Channels: 1-737
Telescope: SWIFT Instrument: XRT Channel Type: PI
Exposure Time: 5.241e+04 sec
Using Background File          PKS0745-19_PCbck.pi
Background Exposure Time: 5.241e+04 sec
Using Response (RMF) File      swxpc0to12s0_20010101v011.rmf for
Source 1
Using Auxiliary Response (ARF) File PKS0745-19_PC.arf
```

Screening

```
XSPEC12> ignore bad
```

```
ignore: 66 channels ignored from source number 1
```

Define a Model

Power-law spectrum

$$F(E) = k E^{-\Gamma}$$

Very common in high energy phenomena

```
XSPEC12> model powerlaw
```

```
Input parameter value, delta, min, bot, top, and max values for ...
```

```
    1   0.01    -3     -2      9     10
```

```
1:powerlaw:PhoIndex> 2
```

```
    1   0.01    0     0   1e+24   1e+24
```

```
2:powerlaw:norm> 1
```

```
=====
Model powerlaw<1> Source No.: 1 Active/On
Model Model Component Parameter Unit  Value
par comp
  1 1 powerlaw PhoIndex    2.00000  +/- 0.0
  2 1 powerlaw norm       1.00000  +/- 0.0
```

Chi-Squared = 5.396967e+09 using 671 PHA bins.

Reduced chi-squared = 8.067215e+06 for 669 degrees of freedom

Null hypothesis probability = 0.000000e+00

Current data and model not fit yet.

Multi-Component Models

A power law with a Gaussian spectral line

```
XSPEC12> model (powerlaw+gaussian)
```

A power law with a Gaussian spectral line and absorption from neutral hydrogen in the Galaxy

```
XSPEC12> model (powerlaw+gaussian)*phabs
```

If you know the value of a parameter freeze it at the known value.

```
XSPEC12> freeze 4  
XSPEC12> freeze 6
```

This freezes parameters 4 and 6 at their input values

Fit the Model

```
XSPEC12> renorm
```

```
XSPEC12> fit
```

```
=====
Model (powerlaw<1> + gaussian<2>)phabs<3> Source No.: 1 Active/On
Model Model Component Parameter Unit   Value
par comp
 1 1 powerlaw PhoIndex      1.40956    +/- 5.84812E-03
 2 1 powerlaw norm        1.01546E-02 +/- 6.16225E-05
 3 2 gaussian LineE      keV       35.1129    +/- -1.00000
 4 2 gaussian Sigma      keV       0.100000   frozen
 5 2 gaussian norm       4.27217E-04 +/- -1.00000
 6 3 phabs   nH          10^22     0.251000   frozen
```

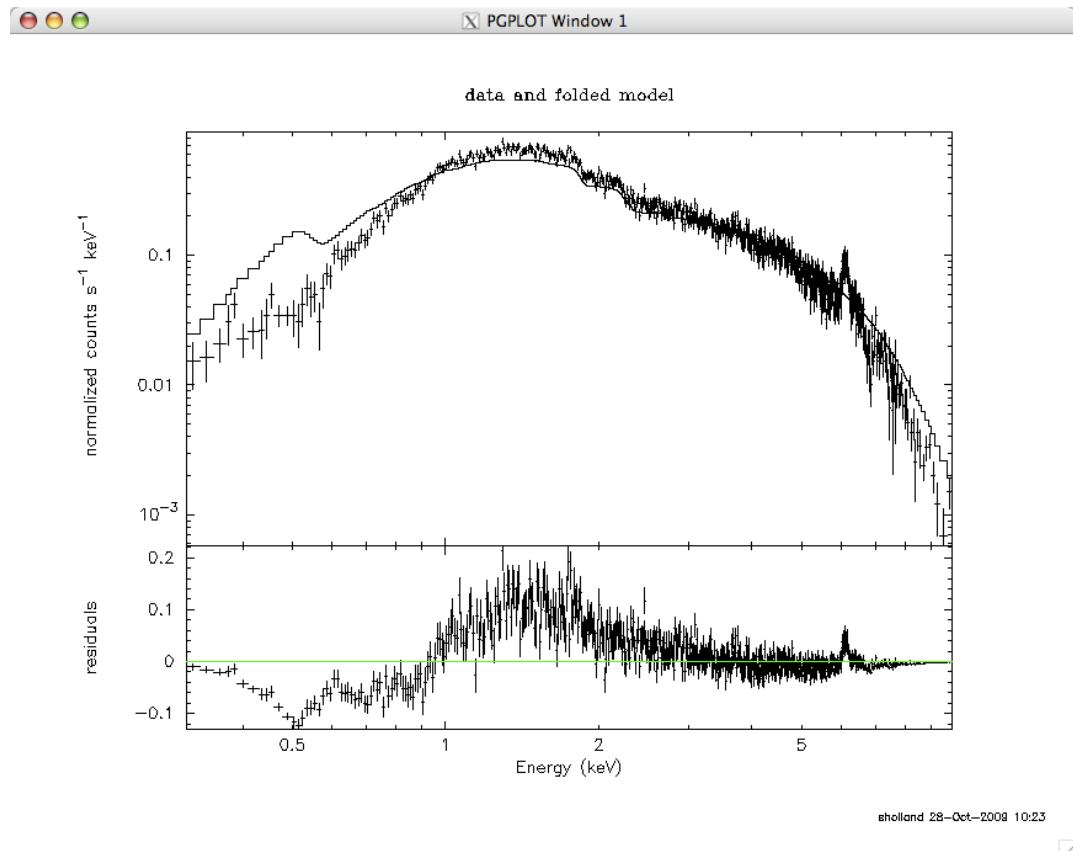
Chi-Squared = 3892.92 using 671 PHA bins.

Reduced chi-squared = 5.83647 for 667 degrees of freedom

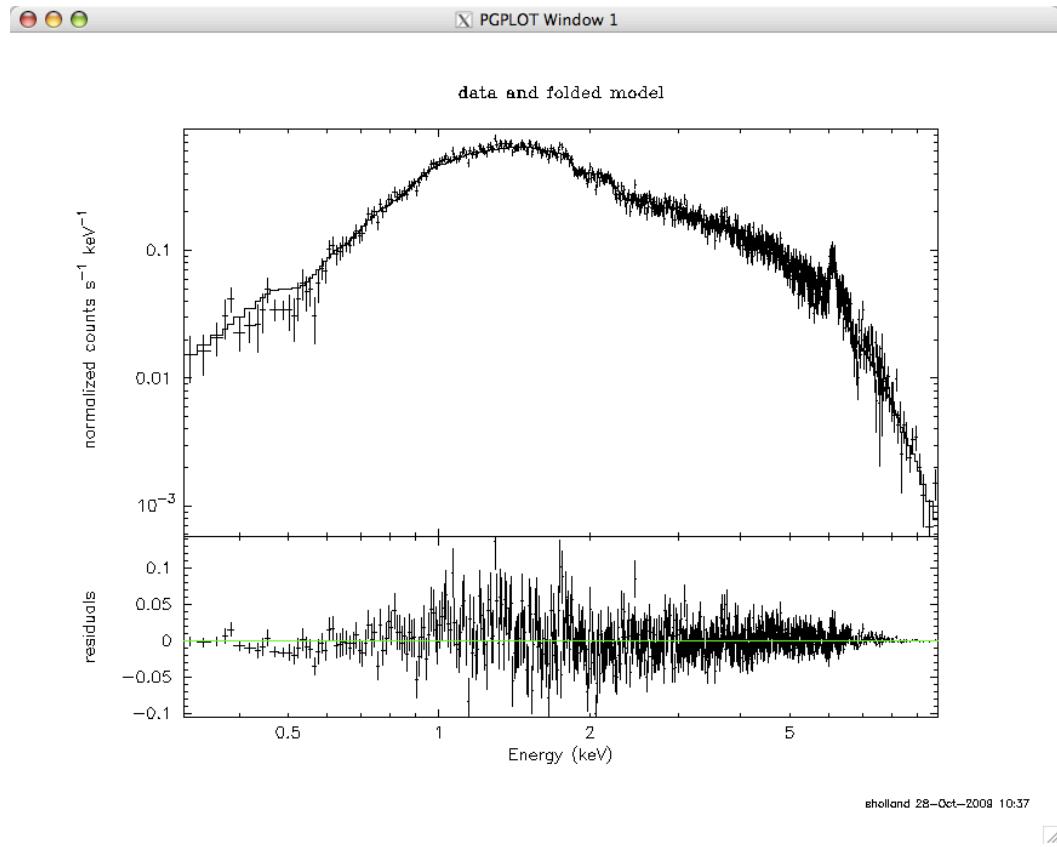
Null hypothesis probability = 0.000000e+00

Plotting

```
XSPEC12> plot ldata residual
```



Can refine the model until it gives a good fit.



To get help type “help” and the prompt.

To get help on the <command> command type
“help <command>”.